UNCLASSIFIED

NAVAL WAR COLLEGE
Newport, RI

WEATHER: OPERATIONAL CONSIDERATIONS ON THE BATTLEFIELD

by

Barbara L. Brehm
Commander, U. S. Navy

A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature: Barbara L. Brehm, CDR

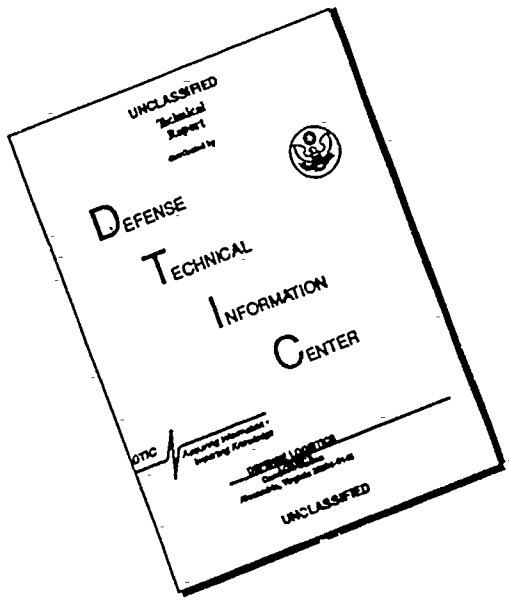
20 May 1991

Paper directed by
T. L. Gatchel
Colonel, U. S. Marine Corps
Chairman, Department of Operations

Approved by:

_____
Date

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION OPERATIONS DEPARTMENT 6b. OFFICE SYMBOL (If applicable) C	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) NAVAL WAR COLLEGE NEWPORT, RI 02841	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

WEATHER: OPERATIONAL CONSIDERATIONS ON THE BATTLEFIELD (U)

12. PERSONAL AUTHOR(S)
BARBARA L. BREHM, CDR, USN

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
FINAL	FROM ____ TO ____	910520	25

16. SUPPLEMENTARY NOTATION A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Operations. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

17 COSATI CODES		
FIELD	GROUP	SUB-GROUP

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
weather control, meteorology, Operation Overlord, Vietnam, Desert Storm, environment, technology

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Weather plays a significant role in the outcome of military operations and its impact has altered over the past fifty years due to changes in technology and forecasting. Advanced technology has not eliminated the need for a battlefield commander to incorporate weather condition limitations into his operational plan however, weather forecasting is at a level where weather can be a proactive factor in planning an operation. The case studies of Operation Overlord, Vietnam, and Desert Storm are reviewed to identify the changing impact of weather on U.S. military planning. This paper focuses on weather's impact on Navy warfare tasks and does not address terrain, hydrography, or the impact of weather on military personnel. Weather control as a weapon is also considered with emphasis on research efforts by the Soviet Union. Commanders must be taught to prepare plans by using weather as a force multiplier. Weather control research by the United States should continue for defensive reasons, and designs for new military equipment mustincorporate methods to overcome limitations imposed by weather.

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL CHAIRMAN, OPERATIONS DEPARTMENT	22b TELEPHONE (Include Area Code) 841-3414 / 22c. OFFICE SYMBOL C

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

0102-LF-014-6602

Encl (2)

Abstract of

WEATHER: OPERATIONAL CONSIDERATIONS ON THE BATTLEFIELD

Weather plays a significant role in the outcome of military operations and its impact has altered over the past fifty years due to changes in technology and forecasting. Advanced technology has not eliminated the need for a battlefield commander to incorporate weather condition limitations into his operational plan; however, weather forecasting is at a level where weather can be a proactive factor in planning an operation. The case studies of Operation Overlord, Vietnam, and Desert Storm are reviewed to identify the changing impact of weather on U. S. military planning. This paper focuses on the weather's impact on Navy warfare tasks and does not address terrain, hydrography or the impact of weather on military personnel. Weather control as a weapon is also considered with emphasis on research efforts by the Soviet Union. Commanders must be taught to prepare plans using weather as a force multiplier. Weather control research by the United States should continue for defensive reasons, and designs for new military equipment must incorporate methods to overcome limitations imposed by weather.

I. INTRODUCTION

In this era when many believe that advanced technology can fix any problem (natural or man-made) that might occur, there remains a frontier that is largely untamed: the weather. A battlefield commander must consider the weather as a major factor when planning his operations for many times it has been this 'weather friction' that stopped an offensive operation.

FM 100-5 notes that the environment of combat includes topography (terrain), hydrography (oceanography) and climate/weather.[1] These items are seen as controlling the employment, movement and resupply of troops as well as serving as cover for their activities. The scope of this paper focuses on only the weather. Weather includes such items as rain, snow, sleet, hail, fog, clouds, wind and darkness.

It is the aim of this paper to briefly review weather as a battlefield concern for the commander and his planners. The analysis discusses how recent advances in forecasting have allowed weather to become a positive planning factor for military operations. Next this paper reviews three cases showing how advanced military technology and forecasting have helped overcome some of the limitations imposed by weather conditions. Finally the paper reviews the upcoming issue of weather control as a weapon including its feasibility and its legality, coupled with the need for a defensive plan to prevent some nation from using weather control against the United States or its allies.

Part of the focus of this paper is the specific impact of extreme weather conditions on Navy warfare tasks as expressed in

Navy weapons, sensors and platforms, and how overcoming these conditions must be factored into the development of new equipment. Limited review is given to the impact of weather on military personnel as that is a topic for an entire, separate paper. It is the thesis of my analysis that advanced technology has started to overcome weather limitations and we must systematically develop our ability to use the new capabilities, that are less weather dependent, when preparing battlefield plans. Therefore, greater emphasis must be placed on training operational commanders to employ weather to their advantage.

In reviewing the effects of weather on the historic battlefield, I intend to examine them pertaining to air, sea and land battlefields. For the current operational environment, I do not aim to specifically note the weather limitations on every U.S. weapon system, but only to discuss the aggregate effect for planners.

In order to gain perspective on the problem, several operational case studies; Operation Overlord, Vietnam, and Desert Shield/Desert Storm; were analyzed and they outline how weather played out in each senario. For example, the weather requirements for Overlord indicated how a commander can optimize his planning for weather, and also how he can employ a lucky break that deceives the enemy. The non-combatant factors of weather on sea and air lift are also examined.

The more recent conflicts of Vietnam and Desert Shield illustrated the advances in weather forecasting and how this updated information was employed in only a limited way by the

operational commanders. Finally to wrap up the historical analysis, the FY92 Meteorology Master Plan was examined as it outlines the weather warfare requirements planning for the future U. S. Navy.

Weather control can be a weapon. The U.S.S.R. has done extensive research in this area due to a considerable domestic need for better weather forecasting and an improvement in agricultural climatic conditions. This opens the way to eventually controlling the weather which could be an excellent long-term (and covert) weapon. Unfortunately the current feasibility of weather control seems limited due to problems in localization and intensity of effect. Also the international community, ever more mindful of the interdependencies of the Earth's ecology, are seeking legal restrictions on such weather control research. Additionally in the the area of weather control, this paper examines the potential need for a defense against weather control by one's enemy.

II. WEATHER AS A BATTLEFIELD CONCERN

Operational commanders have always had to take the weather into consideration when preparing their battle plans. By looking at three modern military operations, I intend to analyze how weather has changed as a force multiplier due to better prediction/forecasting, and due to technological advances in our military systems.

Overlord, the invasion of Nazi-held Northern France, is the first case for review. Overlord was planned by a combined staff

and this is also true for the weather forecasting function. J. M. Stagg had the difficult task to blend inputs from three distinct groups who used different methods and models, and to then produce a consensus, single forecast. His recommendation about the weather was a critical 'GO-NO GO' factor for General Eisenhower to consider. '...the selection of the actual day would depend upon weather forecasts.'[2]

The initial task for Stagg and his group was to get from the Chief of Staff to the Supreme Allied Commander (COSSAC) the meteorological parameters needed for a successful invasion. These had to be based on the operating limits of the military equipment to be used in the invasion. What was good weather for some elements of the invasion force was incompatible with what was required by other elements. 'Every group wanted the 'best'weather for its particular part of the operation, and as there was no one best weather which suited all, this criterion was clearly going to reduce to vanishing point the number of days in any one summer on which Overlord would be launched'.[3] At least they all agreed they would like to have three good weather days post-invasion for resupply.

The meteorologists then revised their approach and attempted to elicit from the operational planners those weather factors which could defeat the invasion all on their own. This approach helped as it limited potential invasion days to when the phases of the moon were favorable for parachute drops and glider landings, plus provided suitable beach tides and limited amounts of fog or mist.

Since 1944 had to be the year for the invasion due to Soviet political pressure, COSSAC naturally focused on an early summer invasion to give themselves as much good "summer weather" as they could get to reconquer Europe. May had been the initial target month, but it was slipped to June partly for logistical reasons (including getting a final shipment of those precious landing craft).

The COSSAC weather group had a body of historical data on weather conditions for the English Channel area. Some current data was supplied to Stagg from ships in the North Atlantic. As Germany had few ships in this area in 1944, COSSAC had an informational advantage in predicting the weather. A critical feature of the Overlord weather analysis was the area for which a forecast had to be made. Both the area where an operation is launched from and where it is to occur have to have "acceptable weather". Also the path between these two areas must meet certain minimum meteorological conditions (unless you can re-route your operation). In Overlord, these areas basically covered both sides of the English Channel plus airbases in Southern England and airheads inland in Normandy. The area that Eisenhower had to consider was far smaller than that considered in Vietnam or for Desert Storm.

The COSSAC needed a long-term, reliable forecast. Based on the technology of forecasting at the time and the unpredictability of English weather, such a forecast was not possible and the weather became Eisenhower's great worry. "Unless Channel weather in 1944 turns out to be wholly exceptional, the production of

regular forecasts which have any true scientific validity or worthwhile dependability is likely to be out of the question for more than two days ahead."[4] As it took at least two days to get all the troops embarked, this weather gamble was a critical one.

As Overlord played out, weather changes were a vital part of the success of the operation. The invasion was planned for 5 June 1944, but forecasts indicated that weather conditions would not meet minimum specifications for the first assualt landings and these, of course, were foundation blocks of the whole operational plan. If the weather did not improve dramatically, the invasion would have to wait until 17-21 June (which it turned out had the worst June storm in 20 years)[5]. So the storm of 4-5 June postponed Overlord.

Stagg and his group had noticed the potential for a single day of acceptable weather based on reports from North Atlantic ships. That day was Tuesday, 6 June. It would allow for two critical sets of assaults (one at dawn and the other at dusk) before a second weather front would move through and severely limit air operations. One question was were the Germans able to discern this one day window or would they assume the whole period was inapproprate for the invasion. Plus, would the weather really hold for the needed 24 hours and would the invasion run according to plan and get the critical assaults in on time?

The Germans missed the one day window and so had let down their defensive guard (in fact, General Rommel had left the area as he felt no invasion was possible). General Eisenhower had not used any of the eighteen days in May that had favorable weather

conditions so the Germans assumed he would not pick to invade during the marginal June weather". And while the follow on weather was so terrible that it churnned the Channel into tearing up the artificial harbors (mulberrys) that had been built, the first two assaults did get in safely. Still the post-invasion storm made resupply by air and sealift difficult and air cover to assist the breakout was limited until the storm cleared. "Thus it came about that the storm of June 4th/5th served General Eisenhower doubly. It kept the reconnaissance aircraft of the enemy on the ground and his naval patrols in harbor so that the abortive start of Overlord was not spotted...".[7]

The analysis of Overlord gives us several operational lessons learned. First, the battlefield commander must define his meteorological requirements in terms of minimum conditions in which his most critical equipment can operate. No commander will ever get totally ideal weather conditions and so he must define what will satisfy various elements of his operation. Secondly the entire area of the operation must be considered plus the path that the operation must follow. Finally, the timing of acceptable weather may be very limited so operational plans need to establish phases into which they can be segmented.

Vietnam was not a single operational campaign, but I believe that several meteorological lessons can be distilled from the years of military activity. In 1968, General Creighton W. Abrams wrote, "Never in the history of warfare have weather decisions played such an important role in operational planning as they have in Southeast Asia."[8] Weather delayed or cancelled operations and

placed limitations on the "high tech" advantage the United States had over North Vietnam.

Post World War II had been a time of significant growth in the field of meteorology. The build up of military manpower in Vietnam included a growth in meteorological support. Unfortunately the Air Force followed the one-year Vietnam tour policy and this caused a lack of continuity of staff and prevented meteorologists from mastering tropical forecasting.[9] And as many Air Force forecasters had gained their operational experience supporting the Tactical Air Command and the Stategic Air Command, they were ill prepared to provide the types of weather support required by ground units.[10] To be fair to the Air Force, 2/3 of forecasters noted on their detaching reports that Army leaders in the field were unaware of or had little use for the meteorological products produced.[11] Nor did they have the knowledge to turn such information into a force multiplier. Tactical communication, the lack of logistical support and over-sophisticated field equipment impeded Air Weather Service (AWS) products.[12] "The hurdles to furnishing satisfactory support to the Army in 1978 were, by and large, the same ones that blocked the path for over thirty years."[13]

Still the AWS work was critical as it helped the B-52s (with the assistance of ground fixes) to become the night, all-weather bombers of choice.[14] This capability enabled the U.S. forces to hit strategic targets at any time. Unfortunately the North Vietnamese were smart enough to dispurse its idustrial targets so bombing had less impact.

One significant improvement that the U.S. military commanders had in Vietman was a better quality of aerial photography, but this was '...extremely weather dependent'.[15] Heavy clouds routinely obscured reconnaissance sites. Weather as a known battlefield consideration took a bigger leap forward because of TIROS III. 'Unquestionably, the greatest technological advance that military meteorologists used in Vietnam was the weather satellite'.[16] Even several Navy carriers purchased receivers to get civil weather satellite photos and this dramatically improved their forecasts.[17] These were critical when trying to coordinate (with the Air Force) strikes coming in from the South. With higher quality data, the forecasting became that much more accurate, and therefore extended the operational planning window. Considering the difficulties imposed by the tropical weather such as monsoons and clouds, the higher quality of forecasting was sorely needed. 'The satellite picture allowed us to launch a mission with a reasonable probability that favorable conditions would prevail at the time the strike forces arrived...'[18]. Also the satellites were critical as Air Force bombing runs were launched from further away than in previous conflicts, so once again the forecasting area was expanded.

'...the elements (of weather) helped to make it a miserable war'.[19] The Army used helicopters extensively to increase mobility and firepower in the jungle environment. Yet helicopters were very susceptable to the extreme Vietnamese weather conditions. 'They (helos) could not operate in zero-ceiling and zero visibility conditions. The crew had to see the target. Helicopter gunships

were not equipped to deliver ordnance through clouds or heavy haze."[20] This indicates that technology had solved only half of the issue. "We could never get the recce (reconnaissance) people to use a system of optimizing their scheduling of targets based on weather". [21] This resulted in less air support than what the ground commanders wanted.

Air Force operating methods had parallel problems as many strikes did a "weather divert" to a secondary or tertiary target before they even left their airfields.[22] If the primary target was critical to the success of some ground operation, it seemed it was beyond anyone's control because of the weather. Also weather over non-combat areas had an impact on Air Force plans as thunderstorms could disrupt the Loran-C navigational signals used by F-4s on some bombing runs. Therefore, the increased accuracy of bombing gained by using the technological advancement of Loran-C was very weather dependent.[23]

The enemy was proactive in using the weather as a screen for their operations. "Under the cover of the heavy fog some audacious North Vietnamese gun crews positioned their antiaircraft weapons just off the runway's eastern end and fired in the blind whenever they heard the drone of incoming aircraft."[24] Such tactics helped the enemy gain substantial advantages. The U.S. also made some minor adjustments to use such things as early morning haze for cover of routine base activity before taking shelter from the usual midday shelling.

Vietnam was notable as the U.S. not only forecast the weather (and made battlefield adjustments), it also tried to change the

weather. Rain making efforts were a significant step towards using weather as a controllable battlefield condition.[25] The Air Force used silver iodide to seed monsoon clouds from 1967 to 1972 and some areas received thirty percent more rain than was normal which of course slowed enemy resupply capability. This effort was viewed as having saved the lives of some U.S. ground troops with only a limited cost.

In summary, the battlefield commander saw several notable changes in meteorological activity in Vietnam. There was a higher level of support (although it appears that both Army and Air Force commanders were not sure how to use it). There was greater accuracy in the weather product produced thanks to satellites and it covered the extended operating areas of the Navy and Air Force. Thirdly, the U.S. tried to alter the weather patterns for military purposes with some limited success.

Desert Shield/Desert Storm is the final operational case study for review. The first operational lesson is that the meteorological task expanded in complexity to include such items as predicting drift/dispursal patterns for oil slicks and all types of chemical or biological weapons in addition to producing routine forecasts. It appears that often raw data was available when the users (so pressed for time) really needed an analyzed product (eg a chemical dispursion matrix).[26] The high tech weapons that made Desert Storm such a success required greater amounts of meteorological data to ensure that they were used within their operating parameters. This data was collected and used effectively. Fortunately the active fighting took place during

cooler weather which allowed a greater use of the advanced weapons and sensors.

As mines were a significant factor in the conflict, the drift models were important and seemed somewhat effective as far as they went. Still the whole meteorological effort was not always high tech as some forecasters used the smoke plumes over Kuwait to judge the direction and strength of surface winds.[27]

Obviously the conflict resulted in several significant lessons learned. Many of the early analyses point to a need to get weather data to the consumer on a real time basis (eg dedicated communication lines, supported by high speed fax machines,were needed for weather information) and liaison teams were needed to integrate joint weather data.[28]

Still the basic elements of weather played its typical part on the battlefield. Smoke over Kuwait hampered air ops and gunnery visibility, the heat caused equipment breakdowns and exhausted personnel who were not acclimatized, and dust brought by the shamal winds got into everything resulting in continuous maintenance requirements.[29]

In all, Desert Shield seemed to teach us more about the administrative flow of meteorological data instead of how to best use qualitative technological improvements. It appears the needed data existed but was not always analyzed or did not get to the intended user in a timely manner. I could find no data that suggested major operations had to be cancelled due to extreme weather conditions except for the amphibious rehersals which lost out to heavy seas. Since B-52 bombing runs came out of Diego

Garcia and the United Kingdom, the forecasting area again took a significant leap in scope.

The Navy now appears to be learning to be mindful of the operational and tactical constraints caused by weather conditions. The FY92 Meteorology Master Plan attempts to indicate those areas where more can be done to support the battlefield commander and to use past lessons learned.[30] It clearly outlines where the oceanographic community in the Navy must go in order to meet the challenges of the future. For example, it points out the need for a reliable 10-14 day forecast to support strategic planning.[31]

The FY 92 Master Plan acknowledges the need for tailored products that specifically address those areas required by a battlefield commander. By comparing 'Meteorological Support Requirements' to the actual products that can be produced, one can identify the meteorological data that is still missing (capability shortfall). What is exceptional is that the master plan then evaluates those shortfalls to determine the level of risk it imposes in each specific warfare area.[32] These risks can then be addressed as we design new weapons, sensors, platforms and tactics.

For instance, routinely weapons, sensors and platforms employ infrared, electro-optical or microwave technologies that did not exist even a few years ago. The employment of these in our over-the-horizon (OTH) operations can be restricted if we do not handle the refraction problem correctly. A Naval Warfare Environmental Sensitivity matrix was developed to highlight the warfare areas that are most sensitive to selected environmental conditions.[33]

The sea control and power projection functions such as ASW/AAW/ASUW/STW/AMW clearly show the greatest sensitivity as opposed to logistical or construction functions.

The Navy's ability to develop global forecasts has helped in the dimension of extended operational areas and much of this is based on better analysis of historical data plus satellite imagery. Still there are significant areas of the world with high military value (eg the Artic) where our ability to operate would be constrained as our weather forecasting would be less accurate. Current models also need to keep up with changing climatic conditions as this can have a significant impact for EM systems, communications equipment and radar.

The safe operating of systems is also dependent on accurate forecasting. As some systems have limited operational windows, they can be used in only certain conditions, otherwise collateral damage is likely to occur. Countermeasures, such as chaff, are also weather dependent and some historical models used for these systems need updating.[34]

As was mentioned in the analysis of Desert Shield, meteorological data transfer is a major battlefield weakness. Weather data's usefulness is very perishable so it must be collected, analyzed and employed quickly and systematically to receive the most benefit. Data receivers have to be improved to keep up with sensor developments.[35] Obviously meteorological conditions become factors in the selection of the appropriate sensors for a particular battlefield problem.[33]

Each warfare area has critical areas of meteorological

shortfall such as a need for better surf models for amphibious warfare. TLAM needs better GO-NO GO decision models.[36] Even in the area of mobility and logistics there are needs for upgrades in weather data transmission. In the current era of restricted budgets, it will be difficult to find the funding to address these meteorological shortfalls.

The area of Naval Special Warfare is of great interest as those forces may be desirous of using poor weather conditions as cover for their operations and so they too need more accurate forecasts.[37] Alternatively they need selected minimum conditions as set by their equipment to perform insertion and extraction operations plus their communications equipment must be able to overcome as many weather-induced limitations as is possible.

C³I is deeply effected by environmental conditions in such factors as attenuation, refraction, reflection and diffraction. The benefit of having multiple, high tech sensors is that you might have one that is well suited to the environment you are experiencing at any given moment. Even the transmission of environmental data to field commanders is subject to interruption by electrical storms and other atmospheric conditions. "Improvements in satellites and sensor systems expects in the 1990's approach an all-weather,day/night capability".[38] This gives a battlefield commander a reliability of systems never enjoyed before. But he must control the tempo of action far more carefully as there are now no "natural breaks" for resting the troops as there once had been.

The FY 92 Meteorology Master Plan outlined the environmental

impact on logistics, mobility and support activities. High temperatures and humidity can degrade stored commodities such as explosives or high tech sensor parts. Lightening and wind can be a significant hazard during underway replenishment or in-flight refueling. Explosive ordnance disposal and towing/salvage have minimum conditions in which they can occur. All of these factors must be considered as an operational commander builds his forces towards a particular campaign.[39]

In all, the FY92 Master Plan clearly detailed meteorological requirements and shortfalls for all Navy warfare areas. Operational commanders need to know the limits of what they got in current environmental support so that they are particularly aware of its impact on sensors, weapons and platforms. When preparing a commander's estimate of the situation, integrating weather patterns into battlefield plans must be part of the thought process on considerations affecting the possible courses of action. It also must be a significant part of the analysis of the characteristics of the logistical operational area. Of course, all commanders, at every level, must be mindful of the effects of the weather on their troops and ensure proper acclimatization is conducted for their personnel.

While meteorological information is now global in nature, there are significant regions that lack the required, detailed data bases for superior prediction. "Climatology records may be nonexistent in many areas, especially in harsh environments such as the artic. In other cases, when studies do exist, data are often sparse and outdated..."[40] These obviously leave the

battlefield commander with a less exact ability to operate in these areas and especially to conduct long range planning.

III. WEATHER CONTROL AS A WEAPON

'If an enemy could control the weather, he would have a powerful weapon indeed.'[41] The goal of such a weapon would be to disrupt enemy military operations, to covertly attack his agricultural base or to provide favorable weather conditions for friendly military operations.

In the past, the operational commander took the weather as a given and planned around it. Now there is the potential to try to alter weather conditions. Dr. Gordon J. F. MacDonald noted in 1975, 'I can see only two circumstances in which weather modification could be usefully employed by the United States as a weapon of war. First some fundamental breakthrough might make weather modification a weapon of mass destruction...The other possible use of weather modification is its employment in a covert war.'[42] He went on to note that with our current nuclear arsenal, we really did not need any more weapons of mass destruction. Still there is a potential to use weather control in a less extreme manner for military purposes.

Early research in weather control focused on using existing clouds and seeding them to produce rain for agricultural purposes. Other researchers also tried to seed the walls of a hurricane to alter its projected course away from a populated landfall. There does appear to be data that suggests these efforts met with at least limited success. But these early pieces of research need to

be expanded so that there is greater precision in the results of weather control and its direction can be more accurately predicted. Plus weather contol must be applied at a specific time or it will not have the required effect.

In 1966, CAPT W. L. Somervell, Jr., USN noted, "We feel that we can start the systematic experimentation that will lead to operationally useful weather modification."[43] But he went on to limit weather modification to such activities as dispursing fog so that aircraft could be launched or recovered, or so amphibious landings could be conducted. The Air Force conducted fog seeding operations in Vietnam in 1967-68 but switched to ground based propane seeding in 1972-73 with good results. Still the actual effect of weather was not viewed as an employable weapon.

The Soviet Union has been highly interested in weather control research and it would have an obviously great domestic application for their agriculture base. But if you can achieve control domestically, then you can get some form of control for military use. The full extent of their capabilities is unknown. "The greatest success at storm modification appears to be that of Soviet scientists...".[44] Destructive hailstorms seem to be one area of their focus. In 1975 the U.S. attempted to formalize banning weather control with the Soviet Union but no binding agreement was signed.

There are significant legal ramifications in using weather control. Many nations have formal regulations and there have been attempts to institute international control. In the U.S. there were hearings and reviews in the 1970's and many states license

practioners of weather control.[48] Damage suits have been filed for those suffering flooding or drought alledgedly caused by weather control research.

Battlefield commanders must work towards using weather control to their advantage, especially when a new technology gives one's side some advantage to overcome a particular weather condition. Commanders must also work to defend against the weather so that it does not blind one's sensors to what the enemy is really doing. A defense must also be prepared so that an enemy can not use weather control to attack the U.S. food supply or our sea lines of communication.

IV. CONCLUSIONS AND RECOMMENDATIONS

As we have seen, environmental factors come in many forms. Their location, intensity and timing have great impact on when military operations can be carried out successfully. Their collective impact on the terrain or ocean can stop a campaign plan or conversely help it to run even better.

The review of the three case studies demonstrated how weather forecasting has grown in sophistication and accuracy. This gives an operational commander a longer planning window and can help him 'hold' an operation for just the right weather conditions. But this requires the commander to be able to clearly articulate the climatic conditions he needs to best employ his troops, weapons, sensors and platforms.

Advanced technology has helped to overcome some weather conditions. Aircraft now fly in stronger winds than previously

possible and have the ability to divert around severe weather it can not handle. Ships can also divert around dangerous weather and can pick the most advantageous transit path. Advanced metals and lubricants enable ground troops to operate even in the artic and darkness has been overcome through the use of night vision goggles. Space has become the home of our weather satellites which has dramatically improved the quality of forecasting and has expanded the area for which we can give a detailed forecast. As we grow to use space as a possible battlefield, we must learn to effectively employ the environment we experience there.

Still high tech has not overcome all environmental conditions, especially those on the extremes of temperature or wind. There are some sea states in which you still can not launch an amphibious assualt. The operational commander must "get smart" about weather limitations so he can use existing conditions to his advantage. If he has superior knowledge of breaks in the weather then he can use that weather to cover his operation as General Eisenhower did. Weather can slow parts of operations, and considering the complexity of the timing used in Desert Storm, weather conditions can really help or hinder the phasing of forces.

Weather control does not appear to be a feasible weapon of the immediate future. But it is an area we must continue to research as others are likely to continue to push their own efforts. Localization of effect is the most obvious failing, but in a large scale military theater, that may not matter to the enemy. And weather control has the potential to be a truly covert

weapon against an enemy's agricultural base. So for purely defensive reasons, we must continue our current weather control research.

This analysis has shown how much we still merely accept weather as a set condition on the battlefield. Forces have endured harsh weather, but only occasionally has it been employed as a proactive factor for one side. In the past, campaigns were planned around the availability of troops after planting and before harvest seasons. Monsoon and winter seasons were avoided for any military operations. Now we have the equipment that can survive in extreme conditions and the ability to forecast those conditions, and so we must learn to employ the extremes for our military advantage.

ENDNOTES

[1] Department of the Army, Field Manual No. 100-5 Operations (Washington, DC, Department of the Army, 1986), p. 75

[2] John F. Fuller, Weather and War (Scott AFB,IL: Military Airlift Command, 1974), p. 5

[3] J. M. Stagg, Forecast for Overlord (New York: W. W. Norton & Co., Inc., 1971), p. 13

[4] Ibid., p. 38

[5] Ibid., p. 126

[6] Fuller, p. 5

[7] Ibid., p. 125

[8] Ibid., p. 13

[9] Charles C. Bates and John F. Fuller, America's Weather Warriors 1814-1985 (College Station: Texas A & M University Press, 1986), p. 197

[10] Ibid., p. 20

[11] John F. Fuller, Air Weather Service Support to the United States Army, Tet and the Decade After (Scott AFB, IL: Military Airlift Command, 1979), p. 14

[12] Ibid., p. 219

[13] Ibid.

[14] Bates, p. 203

[15] Ibid., p. 204

[16] Ibid.

[17] Ibid., p. 220

[18] Fuller 1979, p. 74

[19] Bates, p. 206

[20] Fuller 1979, p. 209

[21] Bates, p. 207

[22] Ibid., p. 209

[23] Ibid., p. 210

[24] Fuller 1979, p. 23

[25] Bates, p. 231

[26] Richard Hess, Quicklook: Desert Shield/ Desert Storm Lessons Learned (U. S. Naval Oceanographic Office, 13 March 1991)

[27] Ibid.

[28] Ibid.

[29] Ibid.

[30] Naval Oceanography Command, Meteorology FY-92 Master Plan (Stennis Space Center, MS: Naval Oceanography Command, 1989), p. C-1--C-48

[31] Ibid., p. C-9

[32] Ibid., p. C-1--C-48

[33] Ibid., p. C-3

[34] Ibid., p. C-37

[35] Ibid., p. C-33-34

[36] Ibid., p. C-20

[37] Ibid., p. C-29

[38] Ibid., p. C-35

[39] Ibid., p. C-40-44

[40] Ibid., p. C-45

[41] Louis J. Battan, Harvesting the Clouds (Garden City, NY: Doubleday & Company, Inc. 1069), p. xi

[42] U. S. Congress Committee on International Affairs, Prohibition of Weather Modification as a Weapon of War (Washington, DC: U. S. Government Printing Office, 1975), p. 3

[47] Eigth Interagency Conference on Weather Modification, Summary of the U. S. Navy Program and FY 1966 Progress in Weather Modification and Control (Washington, DC: U. S. Government Printing Office, 1966), p.1

[44] Howard J. Taubenfield (ed.), Weather Modification and the Law, (Dobbs Ferry, NY: Oceana Publications, Inc., 1968), p. 7

[45] Committee, p. 23

BIBLIOGRAPHY

Bates, Charles C. and Fuller, John F. America's Weather Warriors 1814-1985. College Station: Texas A & M University Press, 1986.

Batten, Louis J. Harvesting the Clouds: Advances in Weather Modification. Garden City, NY: Doubleday & Co., Inc., 1969.

Department of the Army. Field Manual No. 100-5 Operations. Washington, DC: Department of the Army, 5 May 1986.

Eigth Interagency Conference on Weather Modification. Summary of the U. S. Navy Program and FY 1966 Progress in Weather Modification and Control. Washington, DC: U. S. Government Printing Office, 27 October 1966.

Faulbaum, Margaret C. Air Weather Service in Southeast Asia, 1961-1976. Scott AFB,IL: Military Airlift Command, 1979.

Fuller, John F. Air Weather Service Support to the United States Army: Tet and the Decade After. Scott AFB,IL: Military Airlift Command, August 1979.

Fuller, John F. Weather and War. Scott AFB,IL: Military Airlift Command, December 1974.

Hess, Richard. Quicklook: Desert Shield/Desert Storm Lessons Learned. U. S. Naval Oceanographic Office, 13 March 1991.

Naval Oceanography Command. Meteorology FY92-Master Plan. Stennis Space Center, MS: Naval Oceanography Command, 1 June 1989.

Stagg, J. M. Forecast For Overlord. New York: W. W. Norton & Co., Inc., 1971.

Taubenfield, Howard J. (ed.) Weather Modification and the Law. Dobbs Ferry, NY: Oceana Publications, Inc., 1968.

U.S. Congress Committee on International Relations. Prohibition of Modification as a Weapon of War. Washington, DC: U.S. Government Printing Office, 1975.